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(54) Abstract Title
Diversity combination of direct and trunked communications

(57) A method to improve the quality of received signals comprises two mobile stations 10,12 and a base station 14. A signal F1 transmitted from the first mobile station 10 is received by a base station 14 as well as being directly received by second mobile station 12. The base station which is operating in a trunked mode, transmits the signal to the second station at a different frequency F2. The second mobile station can improve reception quality by using diversity combination techniques to combine the signals received over the different paths F1,F2.

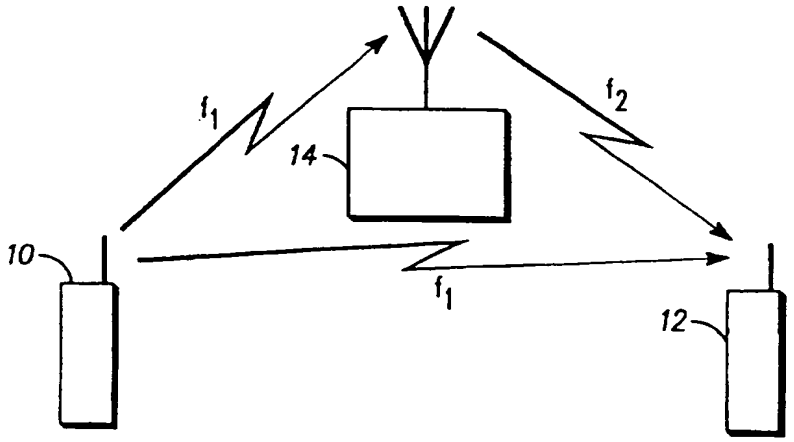

FIG.1

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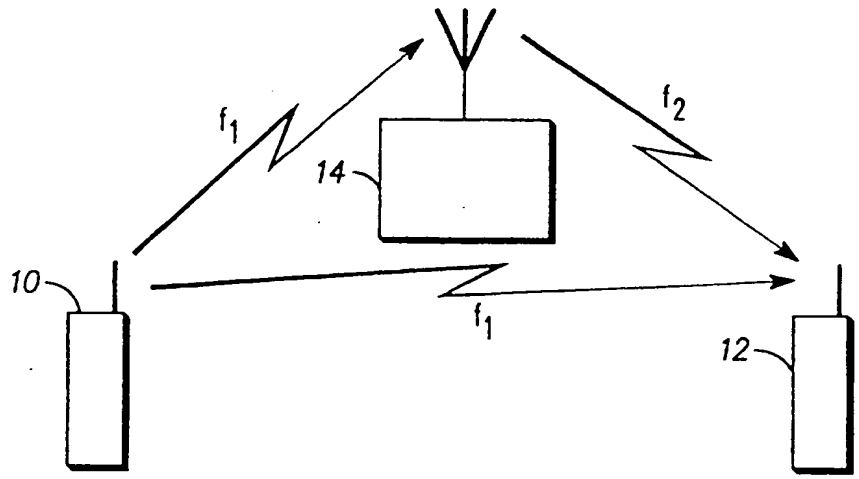
f1
f2
14
10
f1
12

FIG. 1

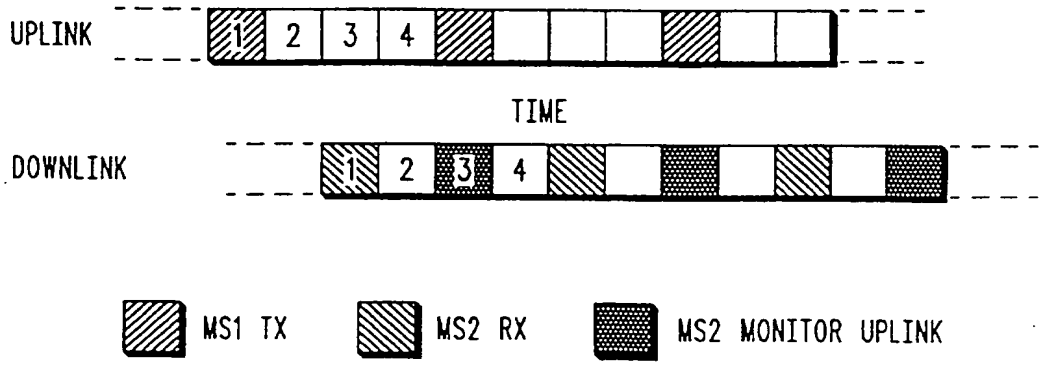
UPLINK
1
2
3
4
TIME
DOWNLINK
1
2
3
4
MS1 TX
MS2 RX
MS2 MONITOR UPLINK

FIG. 4

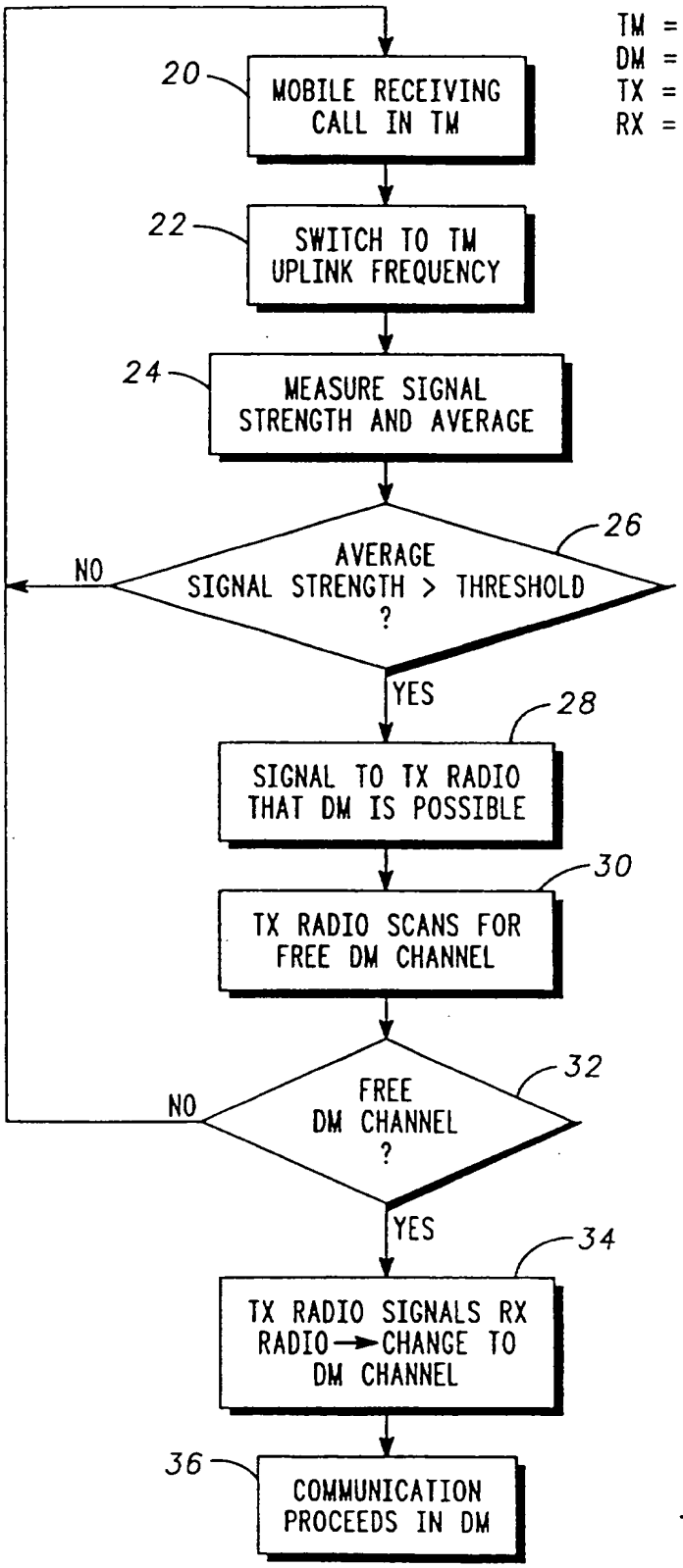
TM = TRUNKED MODE
DM = DIRECT MODE
TX = TRANSMITTING MOBILE
RX = RECEIVING MOBILE
20
MOBILE RECEIVING CALL IN TM
22
SWITCH TO TM UPLINK FREQUENCY
24
MEASURE SIGNAL STRENGTH AND AVERAGE
26
AVERAGE SIGNAL STRENGTH > THRESHOLD ?
NO
YES
28
SIGNAL TO TX RADIO THAT DM IS POSSIBLE
30
TX RADIO SCANS FOR FREE DM CHANNEL
32
FREE DM CHANNEL ?
NO
YES
34
TX RADIO SIGNALS RX RADIO → CHANGE TO DM CHANNEL
36
COMMUNICATION PROCEEDS IN DM

FIG. 2

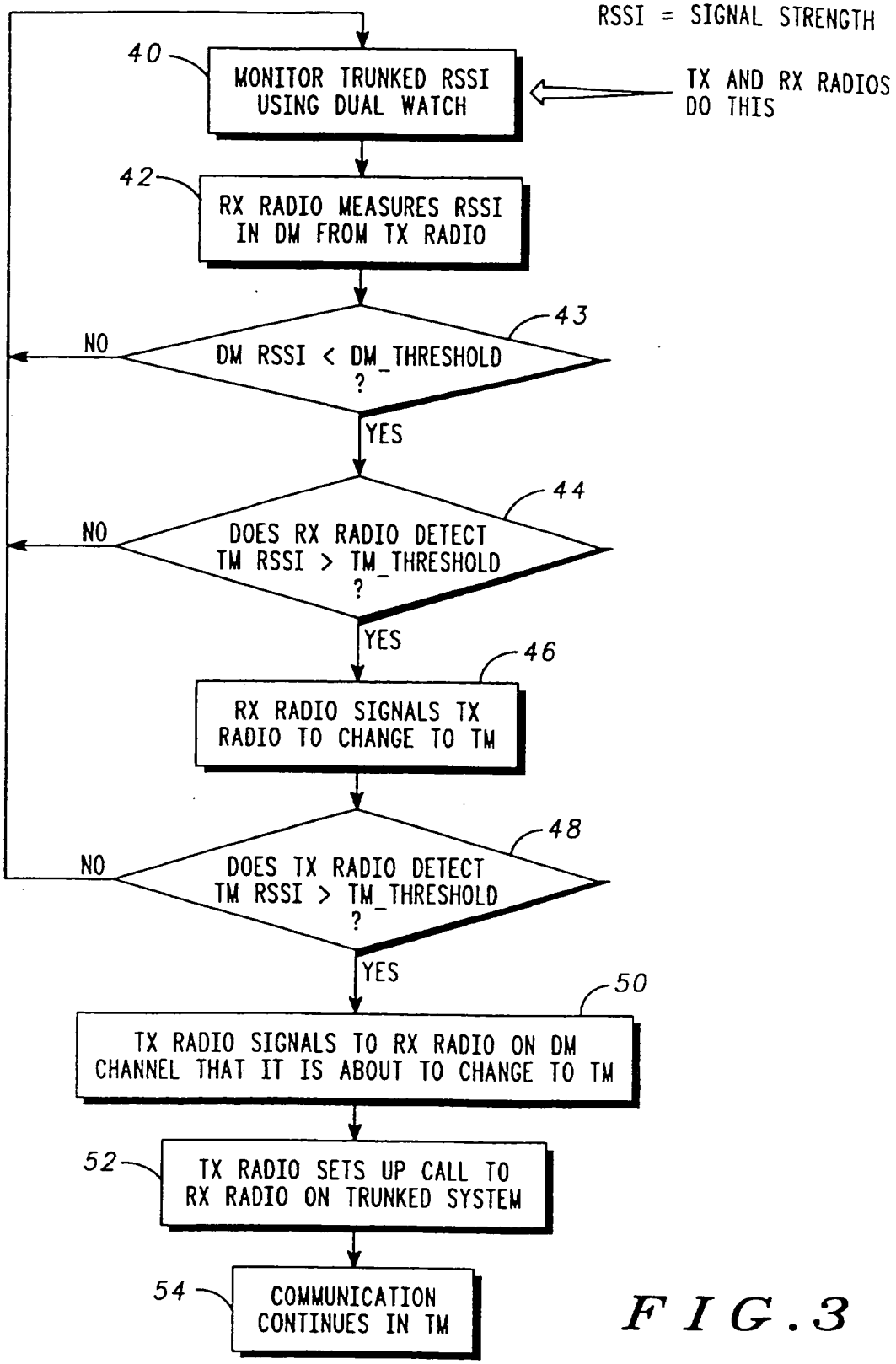
RSSI = SIGNAL STRENGTH
40
MONITOR TRUNKED RSSI USING DUAL WATCH
TX AND RX RADIOS DO THIS
42
RX RADIO MEASURES RSSI IN DM FROM TX RADIO
43
DM RSSI < DM_THRESHOLD ?
NO
YES
44
DOES RX RADIO DETECT TM RSSI > TM_THRESHOLD ?
NO
YES
46
RX RADIO SIGNALS TX RADIO TO CHANGE TO TM
48
DOES TX RADIO DETECT TM RSSI > TM_THRESHOLD ?
NO
YES
50
TX RADIO SIGNALS TO RX RADIO ON DM CHANNEL THAT IT IS ABOUT TO CHANGE TO TM
52
TX RADIO SETS UP CALL TO RX RADIO ON TRUNKED SYSTEM
54
COMMUNICATION CONTINUES IN TM

FIG. 3

METHOD OF DETERMINING COMMUNICATIONS MODE

Field of the Invention

This invention relates to a method of determining a communications mode and optimising the quality of a communication link in a communications system. Specifically, a method of determining a communications mode and handover in a trunked communications system involving direct mode communications.

Background of the Invention

A trunked communications system typically comprises a base station and a plurality of mobile stations. The mobile stations may communicate in trunked mode, via the base station, or in direct mode. A problem with allowing both trunked and direct mode communications in the same system is effectively managing such communications. Mobile stations in direct mode may still need to receive messages from the base station and the base station needs to know where the mobile stations are. Furthermore, mobiles in direct mode may need to switch to trunked mode and vice versa.

A mobile radio operating in a trunked radio system may communicate with other radios in the system via the base station using two-frequency half-duplex operation. In contrast, a radio may also communicate directly with another radio using single-frequency simplex operation. This is also known as direct mode communication.

It may be desirable for two radios communicating in trunked mode to hand over to direct mode communication if they are within direct mode range. This would have the advantage of releasing a trunked channel for other communications which may be beneficial, particularly when the trunked system is heavily loaded.

Conversely, it may also be desirable for two radios communicating in direct mode to hand over to trunked mode communications if the radios are about to move out of direct mode range and are within the coverage of a trunked system.

Handover is a well-known technique used in trunked and cellular communication systems to transfer a mobile radio communication from one base station to another as that mobile radio moves between base station coverage areas. The invention proposes a method for handover from the base station of a trunked system to direct mode where radios communicate without the need for a base station.

There is a need to effectively move mobile radios from trunked mode to direct mode and vice versa in communications systems that allow the different operating modes. Such capability will allow the efficient use of the communications resources as well as improve the quality of the communications.

Summary of the Invention

The present invention provides a method of improving the quality of a received signal in a communications system, the communications system having a base station for trunked communications, and a first mobile station and a second mobile station communicating in a trunked mode. The method comprises the steps of:
(i) receiving a transmitted signal from the first mobile station on a first frequency at the second mobile station and at the base station;
(ii)receiving the transmitted signal from the base station on a second frequency at the second mobile station; and
(iii) using diversity combining techniques, processing the received signals to improve received signal quality.

A preferred embodiment of the invention is now described, by way of example only, with reference to the drawings.

Brief Description of Drawings

FIG. 1 shows a communications system including a base station 14 and mobiles stations 10, 12.

FIG. 2 shows a flowchart of a method performed by the system of figure 1.

FIG. 3 shows a flowchart of a method performed by the system of figure 1.

FIG. 4 shows a frame and timeslot structure for signalling.

Detailed Description of the Drawings

FIG. 1 shows a block diagram of a radio communications system having a central controller or base station 14 for trunked communications. The communications system of FIG. 1 also includes a first mobile station 10 and a second mobile station 12 capable of communicating in trunked mode or direct mode. In trunked mode communications, the mobile stations communicate to each other via the base station. In practice, the transmitting radio 10 transmits a signal on a first frequency, uplink, to the base station which then communicates the signal on a second frequency, downlink, to the receiving radio, downlink. In direct mode, the mobile stations may communicate directly to each other without communicating via the base station.

FIG. 2 shows a method of determining whether to communicate in direct mode in a communications system (FIG. 1) having a first mobile station 10 and a second mobile station 12 communicating via the base station 14. Referring to FIG. 2, a second mobile station 12 is receiving a signal from the first mobile station 10 via the base station on a second frequency (downlink frequency) in trunked mode, step 20. The second mobile station switches to the trunked mode uplink channel, a first frequency, as in step 22. The second mobile station then monitors signals on the first frequency, from the first mobile station, measures the received signal strength and averages as in step 24. A determination may be made as to whether the signal strength average is sufficient, for example, greater than a predetermined threshold, as in step 26. If the signal strength is below a threshold value the mobile stations continue to communicate in trunked mode and the second mobile may periodically monitor the uplink frequency for signals of sufficient signal strength, thus returning to step 20. If the signal strength or signal strength average is determined to be greater than the threshold then the second mobile station transmits to the first mobile station, or transmit mobile, via the base station that they may communicate in direct mode, step 28. The first mobile station, or transmit radio, may then scan for an available direct mode channel, step 30. If there is no direct mode channel available as determined in step 32 the first and second mobile station continue to communicate in trunked mode, step 20. If a direct mode channel is available the first mobile station may signal to the second mobile station to change to direct mode on the available direct mode channel, step 34. A signal may also be transmitted to the base station to inform the base station that the first and second mobile station have left trunked mode communication and are communicating in direct mode on the available direct mode channel. The mobile stations then continue communicating in direct mode, step 36.

FIG. 3 shows a further method. Specifically a method of determining whether to communicate in a trunked mode is shown for a communications system having a base station for trunked communications and a first mobile station and a second mobile station communicating in a direct mode. Referring to Fig. 3, a first mobile station and a second mobile station communicating in direct mode may monitor the trunked control channel average received signal strength, trunked signal RSSI, as in step 40. In step 42, the second mobile station, or receiving radio, measures the average received signal strength from the first mobile station, or transmit radio, in direct mode communication, direct mode RSSI. If the direct mode RSSI is not less than a predetermined threshold value as determined in step 43 then the mobile stations continue communicating in direct mode and continue to monitor the trunked signal RSSI as in steps 40, 42. If the direct mode RSSI is less than a predetermined threshold as determined in step 43, a determination is made in step 44 as to whether the trunked signal RSSI, as measured in

step 42, is greater than a first predetermined threshold. If the trunked signal RSSI is not greater than the predetermined threshold as determined in step 44, then the mobile stations continue communicating in direct mode and continue to monitor the trunked signal RSSI as in steps 40, 42. If the trunked signal RSSI is greater than the predetermined threshold the receive radio transmits to the transmitting radio to change to trunked mode as in step 46. The transmit radio must be able to detect the trunked signals, or the trunked RSSI must be greater than a second predetermined threshold as determined in step 48. The second predetermined threshold may be similar to the first predetermined threshold. If the trunked RSSI is not greater than a second predetermined threshold, then the mobile stations continue communicating in direct mode and continue to monitor the trunked signal RSSI as in steps 40, 42. If the trunked RSSI is greater than the second predetermined threshold the transmit radio signals to the receive radio on the direct mode channel that it is about to change to trunked mode, step 50. The transmit radio then sets up the call on the trunked system, step 53. The mobiles then continue to communicate in trunked mode, step 54.

Thus, by receiving a first transmitted signal from the first mobile station at the second mobile station, receiving channel control information from the base station at the first and second mobile station; and making a determination whether to communicate in trunked mode based the received channel control information, the mobile stations are making effective use of the communications resources. The determination of whether to communicate in trunked mode may be based on the received channel control information and the received transmitted signals.

The present arrangement provides a method for detecting the possibility for handover between trunked mode and direct mode enabled by the use of time division multiplexing in the trunked mode and time burst transmission in direct mode. The arrangement may include a signalling exchange to ensure that continuous communications can be maintained as the radios move between the two modes of operation.

A mobile to mobile communication in a trunked system is conveyed via a base station. A first mobile transmits on an uplink frequency, f_1, to the base station. The base station then repeats this transmission on a downlink frequency, f_2, which is then received by a second mobile. In a TDMA trunked system, the uplink and downlink frequencies are divided into timeslots and thus, a mobile transmitting or receiving only does so for the duration of a single timeslot. Hence transmission and reception is discontinuous.

In contrast, a mobile may operate in direct mode. In direct mode, a first mobile transmits on a direct mode frequency and a second mobile receives on that

same frequency. In a communications system such as TETRA, the first mobile station transmission and the second mobile station reception is discontinuous.

Before being able to hand over a trunked mode communication to direct mode, the communicating mobiles must first establish that they are in direct mode range, as referenced in the discussion of FIG. 2. Such operation is made possible by a TDMA frame structure as used in TETRA which is shown in FIG. 4.

Thus, the operation of the method of FIG. 2 is easily implemented with a TDMA frame structure. Such frame and time slot structure may be used to detect if the mobiles are in direct mode range. The TDMA slot structure is such that there are four slots per frame with a two slot offset between slots transmitted on the uplink frequency and those transmitted on the downlink frequency, FIG. 4. This means that a mobile receiving traffic on a traffic channel by receiving the downlink slots assigned to that channel can also switch to the uplink frequency and monitor the uplink slot of the same traffic channel. In this way, the receiving mobile, as well as receiving the traffic channel transmissions from the base station, can also monitor the transmissions of the transmitting radio. It can determine the signal strength or signal quality of these uplink transmissions in order to determine whether or not the transmitting radio is in direct mode range. Generally, the receiving radio may monitor several uplink transmissions over a period of a few seconds in order average out any fluctuations in the signal level due to fading. The receiving radio may also attempt to decode the uplink transmissions and compare them with the downlink transmissions to ensure that the signal strength being measured on the uplink is indeed as a result of the transmitting mobile and not interference from some other source.

An advantage of the present invention is that by receiving both the uplink and downlink transmissions, a receiving radio has the opportunity to perform diversity combining of the two slots containing the same information which may improve the overall quality of the received signal. This improvement may be useful if either of the mobiles has a poor communication link to the trunked system base station but the mobiles are within direct mode coverage.

As described with respect to FIG. 2, the receiving radio records the direct mode signal strength and when it reaches a level which would support adequate direct mode communications the receiving radio can inform the transmitting mobile.

Thus, having ascertained that the transmitting radio is in direct mode range, the receiving radio can inform the transmitting radio via the base station by using the slow associated control channel (SACCH). This control channel allows a mobile transmitting or receiving on a traffic channel to exchange signalling information with the base station approximately once per second. Using this channel, the receiving radio sends a signalling message to the base station which is then passed onto the transmitting mobile

also using the SACCH. The signalling message has a parameter which can have one of the following values:

1 - Receiving mobile is in direct mode range;
2 - Receiving mobile is out of direct mode range;
3 - Receiving mobile is about to lose system range and is inside direct mode range.

Using such signalling the receiving radio can inform the transmitting radio that it is able to switch to direct mode if necessary or that it has moved out of direct mode range. This allows the transmitting mobile to make the decision as to whether or not to switch over to direct mode. Such a decision may be made automatically or by the user of the radio. If the receiving mobile is about to lose system range, then it can inform the transmitting mobile in order to initiate a handover to direct mode. In all cases, the transmitting mobile initiates any change to direct mode.

Thus, the transmitting mobile can change to direct mode if it has been informed by the receiving mobile that this is possible. As also described with reference to FIG. 2, the transmitting mobile can scan direct mode channels in between uplink transmissions in order to find a direct mode channel that is free. The transmitting mobile then signals to the receiving mobile to change to the direct mode channel by stealing signalling capacity from the traffic channel. This signalling also informs the system that the communication is about to be dropped as the mobiles change to direct mode. The communication then continues on the direct mode channel using the same frame timing to ensure that synchronisation is not lost. In this way, seamless handover can be achieved and communication can be maintained.

As described with reference to FIG. 3, a direct mode to trunked mode handover may also be performed. In order to initiate a handover to trunked mode, the radios must be inside system coverage. In between uplink transmissions, the transmitting mobile can monitor the trunked system control channel frequency and measure the received signal strength in order to ensure that it is inside range of the system. The receiving mobile can also perform such measurements in between receiving bursts on the direct mode channel. In this way both mobiles can ensure that they are inside system coverage before initiating handover.

The receiving mobile may use the reverse signalling channel on the direct mode frequency in order to inform the transmitting mobile that it is inside system coverage and that direct mode range may be failing.

The transmitting mobile initiates the change to trunked mode by informing the receiving mobile to change to the control channel of the trunked system and then

requesting a channel to continue the communication, similar to setting up a new call on the trunked system.

Alternatively, the transmitting mobile may attempt to set up the communication on the trunked channel by signalling in between direct mode communications and then informing the receiving mobile that it has changed to the trunked channel where communication may continue.

The present invention provides a method to apply time diversity to combine a communication which is recieved in direct mode as well as in trunked mode. The present arrangement also provides a method to effectively and efficiently handover between trunked and direct modes of operation within the same communication system. By the use of time division multiplexing in trunked mode and time burst transmission in direct mode, which allow such diversity and handover to be applied with minimal interruption of the ongoing communication, the integrity of the communications is increased. Thus, the present arrangement allows communications systems to implement different modes of operation effectively.

Claim

1. A method to improve quality of a received signal in a communications system having a base station for trunked communications and a first mobile station and a second mobile station communicating in a trunked mode, the method comprising the steps of:

receiving a transmitted signal from the first mobile station on a first frequency at the second mobile station and at the base station;

receiving the transmitted signal from the base station on a second frequency at the second mobile station; and

using diversity combining techniques, processing the received signals to improve received signal quality.

Application No: GB 0104512.9
Claims searched: 1

Examiner: Robert Macdonald
Date of search: 8 March 2001

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.S): H4L(LDST, LDDSF, LDDRS, LDDRCP, LDDRCW, LDDRCX)

Int Cl (Ed.7): H04B(7/08, 7/12); H04L(1/02, 1/04, 1/06); H04Q(7/28)

Other: ONLINE: WPI, PAJ, EPODOC.

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
	NONE	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.